MASTER OF SCIENCE
IN
APPLIED MATHEMATICS

MASTER OF SCIENCE IN APPLIED MATHEMATICS

MATHEMATICAL MODELING USING MAPLE
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Master of Science in Applied Mathematics-September 1996
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The area of higher mathematics begins with successive courses in calculus; however, rarely does the calculus student recognize the applications or impetus for the mathematical skills that are taught. Giordano and Weir produced A *First Course in Mathematical Modeling,* the first text which addressed this shortcoming in the curriculum of every science and engineer field. With the advent of powerful classroom computers, Fox, Maddox, Giordano and Weir produced *Mathematical Modeling With Minitab,* which assists the student in translating the theory into a computer language. At the Naval Postgraduate School, Maple is the software used most commonly in the Mathematics Department, requiring a similar instructing tool. Mathematical Modeling using Maple follows the lead of *Mathematical Modeling With Minitab,* and assists the student in grasping the concepts of the modeling class without getting slowed down by the syntax of Maple.

EDGE ANNIHILATION SEQUENCES FOR CLASSES OF CHORDAL GRAPHS
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Given a non-empty graph $G = (V,E)$ of order n and size m, with some property P, we may ask whether there exists a sequence of graphs constructed by the sequential removal of edges $e_1, e_2, ..., e_m$, with the property that if $G_0 = G$ then (1) G_i obtained from G_{i-1} by deletion of exactly one edge and (2) G_i has property P for $1 - i - m$. We refer to such a sequence as an edge annihilation sequence. If G is chordal, strongly chordal, split, threshold, interval or unit interval, then we show that there exists an edge annihilation sequence for G. Algorithms and necessary vertex orderings are given for the construction of edge annihilation sequences for the above mentioned classes of graphs. We know that for $G^{(n)}$, the set of all labeled graphs $G = (V,E)$ of order n, $(G, -)$ is a partially ordered set (poset) under edge set inclusion. Using edge annihilation sequences and edge completions sequences, we discuss the construction of a chain of graphs in $G^{(n)}$ with property P. We show that within $G^{(n)}$, every graph with property P lies on at least one chain of graphs with property P.

A MATHEMATICAL MODEL ANALYSIS OF MINE COUNTERMEASURES IN A HARBOR CHANNEL
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Master of Science in Applied Mathematics-March 1996
Advisors: Bard K. Mansager, Department of Mathematics
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Mines are extremely effective weapons, they are small, cheap, easy to hide, easy to store, and can be clandestinely laid from virtually any type of platform. They have become the favorite weapon of informal forces, such as terrorists, because they are also very easy to obtain (Eastern Bloc stores, etc.).

This thesis is based on the idea of utilizing the significant threat of the mine to interrupt the sea transportation of a specific harbor by laying mines in the harbor channels. The host country will clear all the mines as soon as possible to insure smooth transportation. By using the Janus war-gaming simulation, three scenarios were created to compare various Mine Counter Measures (MCM) approaches. Each scenario has the same red force (the mines laid in the harbor) against two types of blue forces. The first scenario gives a baseline for what would be expected should no mine

clearing take place. The second one is the current Naval MCM forces, which are mine-sweepers and mine-hunters, of a certain Asian country. The last one applies a new technology, Lemmings, in the MCM force.

A comparative analysis of these three scenarios will be performed, examining the measures of effectiveness of merchant ships killed, time consumption of mine-clearing, and percentage of mines neutralized.

THE USE OF HÉNON BINARY SEQUENCES FOR DIRECT SEQUENCE SPREAD SPECTRUM CODE GENERATION

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In this thesis, the generation of secure codes using chaotic pseudo-random sequences and a generalized Geffe generator is investigated. These codes are tested for cryptographic security and applicability for use in a spread spectrum communications system. It is shown that the codes appear to be cryptographically sound and suitable for use in a multi-user environment, but do not significantly enhance the security of the spread spectrum system. Further simulation of the spread spectrum system is utilized to investigate the effect of errors in receiver spreading codes.

MATHEMATICAL MODELING AND ANALYSIS OF SURVIVABILITY AND MORBIDITY RATES

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The goal of this thesis is to show the feasibility of using Janus(A), a high resolution combat simulator, as a planning and training tool for analyzing, with graphical methods, when and where casualties will occur on the battlefield. These results can be used for estimating the type and number of casualties, and planning evacuation routes, casualty collection points and necessary medical resources.

In order to show the utility of this approach, this thesis presents results from three different scenarios. This will allow the analyst to see how the visualization exhibits the different outcomes. All three scenarios are run with data from the Marine Corps' Operation Kernel Blitz-95, the largest combat medical exercise since the Korean War. Scenario one will be conducted with the amphibious landing force 'bulling ahead' with little to no offshore minefield breaching operations being conducted prior to the assault. Scenario two will utilize a more traditional method of offshore breaching. Scenario three will then use the Autonomous Legged Underwater Vehicle (ALUV) to breach the surf zone mine fields prior to the landing.

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A COMBAT SIMULATION ANALYSIS OF AUTONOMOUS LEGGED UNDERWATER VEHICLES
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Master of Science in Applied Mathematics-June 1996
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Autonomous Legged Underwater Vehicles (ALUVs) are inexpensive crab-like robotic prototypes which will systematically hunt and neutralize mines en masse in the very shallow water and the surf zone (VSW/SZ). With the advent of mine proliferation and the focal shift of military power to the littorals of the world, ALUVs have the potential to fill a critical need of the United States Navy and Marine Corps' mine countermeasure (MCM) forces.

Duplicating the MCM portion of the Kernel Blitz 95 exercise whenever feasible, this thesis uses the Janus interactive combat wargaming simulation to model and evaluate the effectiveness of the ALUV as a MCM. Three scenarios were developed: an amphibious landing through a minefield using no clearing/breaching; an amphibious landing through a minefield using current clearing/breaching techniques; and an amphibious landing through a minefield using ALUVs as the clearing/breaching method.

This thesis compares the three scenarios using landing force kills, cost analysis, combat power ashore, and percentage of mines neutralized as measures of effectiveness.

MATRIX ALGEBRA
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The purpose of this thesis is to develop a textbook which presents basic concepts of matrix algebra from a primarily computational perspective, for an introductory course in matrix algebra at the Naval Postgraduate School (NPS). The need for an introductory matrix algebra text is generated by the unique characteristics of the student body at NPS. Students at NPS are beginning graduate studies after several years away from the academic environment. As a result, most students benefit from a course which presents fundamental concepts and techniques in solving matrix algebra problems which are needed for advanced studies in mathematics, engineering, and operations research. Current publications in matrix algebra go into more detail on linear algebra than is needed for the introductory course and many texts do not cover complex numbers in sufficient detail to meet the needs of the students. This text presents techniques for solving systems of linear equations, the algebra of matrices, the connection between linear systems and algebraic operations on matrices, and an introduction to eigenvalues, eigenvectors, and complex numbers. The intent is to hone student skills in applying fundamental techniques in matrix algebra essential to success in future courses.

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AN ANALYSIS OF LEMMINGS: A SWARMING APPROACH
TO MINE COUNTERMEASURES IN THE VSW/SZ/BZ
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Lemmings are autonomous tracked underwater vehicles which utilize a swarming approach to mine detection and neutralization in the very shallow water, surf, and beach zones (VSW/SZ/BZ). The Navy and the Marine Corps are in great need of developing an effective "in stride" clearance/breaching method to further enhance the effectiveness and viability of their littoral warfare skills. The Lemmings system has the potential to fulfill this critical need in a cost effective, reliable manner.

Utilizing the Janus interactive wargaming simulation, an amphibious operation was modeled, with the amphibious landing taking place through a minefield in the littoral zones. Three scenarios of this model were developed: an amphibious landing through a minefield utilizing no clearing/breaching assets; an amphibious landing through a minefield utilizing current clearing/breaching assets, and an amphibious landing through a minefield utilizing Lemming swarms as the clearing/breaching assets.

A comparative analysis of these three scenarios will be performed, examining the measures of effectiveness of landing vehicles killed/damaged, combat power ashore at a given time, MCM assets killed, and percentage of mines neutralized.

A COMPUTER SIMULATION ANALYSIS OF ALTERNATIVES TO THE M728
COMBAT ENGINEER VEHICLE (CEV)
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This thesis compares the speed of breaching obstacles and the effects on survivability of the force provided by the Combat Engineer Vehicle (CEV) and two proposed replacement alternatives, the M1-CEV and the M1 with Blade, using the Janus (A) combat simulation. By doctrine, engineer units support the maneuver commander by providing the equipment and expertise for breaching operations. The CEV is a critical breaching asset that has reached the end of its operational lifetime. Most units have been ordered to turn in their CEVs by the end of fiscal year 1996. The proposed replacement, the M1 Breacher, is not to be fielded until the year 2000. Also, the M1 Breacher will not be able to perform all of the tasks that the CEV performs. As a result, the Army is seeking an alternative to the CEV to fill the void left by turning them in before the fielding of the M1 Breacher. This thesis examines the effects these three vehicles have on survivability and speed of breaching in a deliberate breaching scenario. Data related to survivability and speed are generated by the Janus simulation runs and analyzed using graphical and statistical methods.